

Vx words

ni.com/wibuilder

$$\nabla \times E = 0$$

CUF 2014 - 15cm

06/03

Q1. a) $\oint \vec{E} \cdot d\vec{s} = \frac{Q}{\epsilon_0} = 0$, pois a carga em um capacitor pontual na superfície.

$$b) \quad E = \frac{\Delta A}{\Delta A} = \frac{\Delta \hat{n}}{\Delta \omega}$$

c) nu în corp electric tangente a suprafeței = 0 (electrostatic); se utilizează în general
și în cazul câmpului electric și al câmpului magnetic și nu în cel electric
Q2
$$\vec{D}(\vec{r}, t) = A e^{i(\vec{k} \cdot \vec{r} - \omega t)}$$
 $\nabla \cdot \vec{D} = 0$

Q2. $d\vec{v}(k,t) = A e^{i(\vec{k}\vec{r} - \omega t)}$

$$T \cdot v = \frac{\partial v}{\partial x} = i\hbar v(x, t)$$

$$\sqrt{x} = 0$$

$$i\hbar \chi v = \begin{vmatrix} x & \hat{g} & \hat{z} \\ i\hbar v_x & i\hbar v_y & i\hbar v_z \\ \hat{p}_x & \hat{p}_y & \hat{p}_z \end{vmatrix} = i\hbar v_x \hat{g} - i\hbar v_z \hat{z}$$

$$i\hbar(v_x \hat{v}_y) \hat{x} + i\hbar(-v_x) \hat{y} + i\hbar(v_y) \hat{z} = -i\hbar v_x \hat{y} + i\hbar v_y \hat{z}$$

$$b) \nabla_{\mathbf{x}} u = \begin{pmatrix} \frac{\partial}{\partial x_1} & \frac{\partial}{\partial x_2} & \frac{\partial}{\partial x_3} \\ v_1 & v_2 & v_3 \end{pmatrix} \Rightarrow -\frac{\partial u}{\partial x} \hat{y} + \frac{\partial u}{\partial x} \hat{z} = [-u(x,t) \hat{y} + u(x,t) \hat{z}]$$

c) direção propagação X.

$$\nabla E = \nabla B = 0 \quad (\text{valor})$$

$$\frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z} = \frac{\partial B_x}{\partial x} + \frac{\partial B_y}{\partial y} + \frac{\partial B_z}{\partial z} \Rightarrow \frac{\partial E_x}{\partial x} = \frac{\partial B_x}{\partial x} = 0$$

não varia em X, direção de propagação
... ondas transversais.

$$\nabla \times E + \frac{\partial B}{\partial t} = 0$$

$$\frac{\nabla \times E}{\omega} = B$$

$$E \cdot B = \underbrace{E \cdot \frac{\nabla \times E}{\omega}}_{=0} = 0 \quad \text{perpendicular}$$

Q3. a) $L = \hbar n$ - um elétron

$$F_{el} = m a_c$$

$$\frac{ze^2}{4\pi\epsilon_0 r^2} = \frac{mv^2}{r} \Rightarrow \frac{r_n \cdot ze^2 \cdot m}{4\pi\epsilon_0} = (\hbar n)^2$$

$$m^2 v^2 r^2 = L^2 = \hbar^2 n^2$$

$$P^2 = \frac{ze^2 \cdot m}{4\pi\epsilon_0 r}$$

$$r_n = \frac{4\pi\epsilon_0 (\hbar n)^2}{ze^2 m}$$

$$b) E = \frac{p^2}{2m} + \frac{ze^2}{4\pi\epsilon_0 r_n} = \frac{ze^2}{2 \cdot 4\pi\epsilon_0 r_n} - \frac{ze^2}{4\pi\epsilon_0 r_n} = -\frac{ze^2}{2 \cdot 4\pi\epsilon_0 r_n} = -\frac{m(ze^2)^2}{2 \cdot (4\pi\epsilon_0 \hbar n)^2} \approx -\frac{13,6}{n^2} \text{ eV}$$

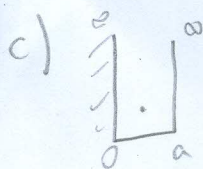
$$\Delta E = E_n - E_0 = -\frac{13,6}{4} + 13,6 = 10,2 \text{ eV} \quad E_0 = -\frac{13,6}{1^2}$$

$$+\frac{E_0}{4} + E_n = -\frac{3E_0}{4}$$

[2]

cont. Euf 2014 - 1sem.

03.



$$\int p dx = hn$$

$$E = \frac{p^2}{2m} = \int_0^a \frac{p^2}{2m} dx$$

$$\downarrow$$

$$p^2 = 2mE \Rightarrow \int_0^a p dx = hn \Rightarrow \sqrt{2mE} \cdot a = hn$$

$$E_n = \left(\frac{hn}{a} \right)^2 \frac{1}{2m}$$

d) $E_n - E_0 = -\frac{3E_0}{4}$

$$\left(\frac{2h}{a} \right)^2 \frac{1}{2m} - \left(\frac{h}{a} \right)^2 \frac{1}{2m} = -\frac{3E_0}{4}$$

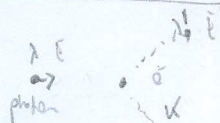
$$E_0 = \frac{e^2}{2(4\pi\epsilon_0)r_h}$$

$$2 \left(\frac{h}{a} \right)^2 \frac{1}{2m} = \frac{3E_0}{4} \Rightarrow \left(\frac{h}{a} \right)^2 = \frac{mE_0}{2} \Rightarrow a = h \left(\frac{2}{mE_0} \right)^{\frac{1}{2}}$$

$$a = \left(\frac{4(4\pi\epsilon_0)r_h}{m e^2} \right)^{\frac{1}{2}}$$

$$\Delta x = x - x_0 \Rightarrow x_0 = x + \Delta x$$

Q4.



$$\lambda' - \lambda = \Delta\lambda = \frac{h}{m_0c} (1 - \cos\theta)$$

$$\frac{hc}{\lambda} - \frac{hc}{\lambda'} = K$$

for max K $\Rightarrow \Delta\lambda$ tempur ser
0 mvd to $\Rightarrow \theta = 180^\circ$

$$E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{m_0c^2} = \frac{h}{m_0c}$$

$$\frac{hc}{\lambda} - \frac{hc}{(\lambda + \Delta\lambda)} = K$$

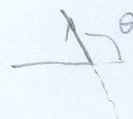
$$\Delta\lambda = \frac{2h}{m_0c}$$

[3]

$$\Delta\lambda = \frac{2hc}{E} \Rightarrow E = \frac{hc}{\lambda + \frac{2hc}{E}} = K_{max} \Rightarrow E = \frac{hcE}{\lambda E + 2hc} = K$$

$$\frac{\lambda E^2 + hcE}{\lambda E + 2hc} = K \quad ? \quad \frac{\lambda E^2 + 2hcE - hcE}{\lambda E + 2hc} = K$$

$$b) \Delta\lambda = \frac{h}{mc} (1 - \cos(120^\circ)) \Rightarrow \frac{h}{mc} = \frac{hc}{\lambda + \Delta\lambda} ; K = \frac{hc}{\lambda} - \frac{hc}{\lambda + \Delta\lambda}$$

c)  $\cot\left(\frac{\theta}{2}\right) = \left(1 + \frac{D_c}{D_0}\right) \tan\phi$ ω descrece ω logarithmic
do momento e calcula
ordens ϕ

OS.

OS. $u \rightarrow 2u_0$ $w?$ $Q?$ (u_0, p_0) e d e c .

$$a) \boxed{W=0}; \boxed{Q=0} \Rightarrow \boxed{\Delta U=0} \Rightarrow \Delta T=0, \boxed{T_2=T_1} \quad \Delta U = nC_V \Delta T$$

$$d(TS) = dT \cdot S + T dS \quad u(T, V) \rightarrow dV = \left(\frac{\partial V}{\partial T}\right)_P dT + \left(\frac{\partial V}{\partial P}\right)_T dP = 0$$

$$d(u-TS) = -SdT - PdV \quad \times \quad PdV = nRST \quad ?$$

$$dT = -\left(\frac{\partial T}{\partial V}\right)_P dV \quad \left(\frac{\partial V}{\partial T}\right)_P =$$

$$dT = -\left(\frac{\partial T}{\partial V}\right)_P dV$$

T =

4

EUR 2014 - 1.5m
ant

08/03/2016

b) $du = T \delta s + p \delta v$

$du = p \delta v$

c) isobare \rightarrow pressure constant

$w = p \cdot \Delta v = p \cdot v_0$

$Q = m \cdot c_p \Delta T = \frac{m c_p v_0}{\kappa}$

$\Delta u = c R \Delta T$

$\Delta w = p \Delta v \Rightarrow Q = \Delta u + w = c R \Delta T + p \Delta v$

$Q = c R \frac{v_0}{\kappa} + p v_0$

$\frac{v}{T} = \kappa$ (constant)
 $v = \kappa T \Rightarrow T_2 = \frac{v_0}{\kappa}$

$T_1 = \frac{2v_0}{\kappa}$

$\Delta T = \frac{v_0}{\kappa}$

d) isotherm $\rightarrow T$ constant

$p = \frac{nRT}{v}$

$\Delta T = 0, Q \neq 0$

$p v = \text{constant}$

$w_{A \rightarrow B} = \int_{v_A}^{v_B} p dv = \int_{v_A}^{2v_0} \frac{RT}{v} dv = RT \ln(2)$

derivative part send the integral

$du = 0 \Rightarrow \Delta u = c R \Delta T = 0$

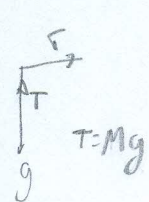
$w = Q$

151

Q6.

A B
m M

work

a)  $E = m v^2 = \frac{m v^2}{r_0} = M g \Rightarrow m \omega^2 r_0 = M g$

$$\omega_0 = \sqrt{\frac{M g}{m r_0}}$$

b) $L = \frac{1}{2} (m+M) \dot{r}^2 + \frac{1}{2} m r^2 \dot{\theta}^2 - m g (r-l)$

$r: \frac{d}{dt} \left(\frac{\partial L}{\partial \dot{r}} \right) - \frac{\partial L}{\partial r} = 0 \Rightarrow \ddot{r} (m+M) - m r \dot{\theta}^2 + m g = 0$

$$\ddot{r} - \frac{m r \dot{\theta}^2}{(m+M)} + \frac{m g}{(m+M)} = 0$$

$\theta:$

$\frac{d}{dt} \left(\frac{\partial L}{\partial \dot{\theta}} \right) - \frac{\partial L}{\partial \theta} = 0 \Rightarrow m r^2 \ddot{\theta} = 0 \Rightarrow \ddot{\theta} = 0$

c) if $\frac{\partial L}{\partial \theta} = 0 \Rightarrow p = \frac{\partial L}{\partial \dot{\theta}}$ conserved

$L = m r \dot{r} = r p = r \times p$

$\frac{\partial L}{\partial \theta} = 0 = p = \frac{\partial L}{\partial \dot{\theta}} = m r^2 \dot{\theta} = L$ (momentum is conserved!)

$r \dot{\theta} = v$
 $m v r$

$\frac{\partial L}{\partial t} = 0 \Rightarrow$ Energy conserved

d)

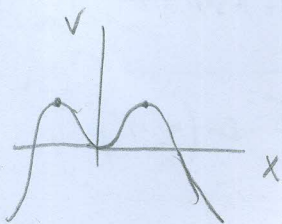
EUP - 2014 Wien

07

$$V(x) = \frac{1}{2} k x^2 = \frac{k}{4a^2} x^4$$

$$\left(-1 + \frac{k}{4a^2}\right) \omega$$

$$a) F(x) = -\nabla V = -kx + \frac{kx^3}{a^2} \Rightarrow F=0 = -kx + \frac{kx^3}{a^2}$$



$x=0 \Rightarrow$ ext. min.
 $x=\pm a \Rightarrow$ ext. max.

$$x \in 0, \pm a$$

$$\omega^2 = \frac{k}{m}$$

$$b) \left. \frac{\partial^2 V}{\partial x^2} \right|_{x=0} = k - \frac{3kx^2}{a^2} = k \Rightarrow m\omega^2 \Rightarrow \frac{2\pi}{T} = \sqrt{\frac{k}{m}} \Rightarrow T = 2\pi \sqrt{\frac{m}{k}}$$

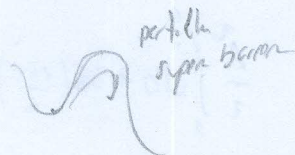
$$c) V(a) = \frac{1}{4} k a^2, F(a) = 0$$

$$\sigma \propto \sqrt{\frac{k}{m}}$$

$$\sigma \propto a \sqrt{\frac{k}{a}}$$

$$E = \frac{m\sigma^2}{2} \Rightarrow \frac{m a^2 k}{2 \cdot 2\pi^2} = \frac{a^2 k}{4}$$

partielle proba
 no prob



$$d) -kx + \frac{kx^3}{a^2} = m\ddot{x} \Rightarrow$$

$$E = \frac{m\dot{x}^2}{2} + \frac{1}{2} k x^2 - \frac{kx^4}{4a^2}$$

$$L = \frac{1}{2} m \dot{x}^2 - \frac{1}{2} k x^2 + \frac{k}{4a^2} x^4$$

$$\frac{m\dot{x}^2}{2} - \left(ka - \frac{kx^2}{a}\right) + \frac{kx^4}{4a^2} = E$$

$$\frac{d}{dt}(m\dot{x}) + kx - \frac{kx^3}{a^2} = 0$$

$$\ddot{x} + \omega^2 x - \frac{\omega^2}{a^2} x^3 = 0$$

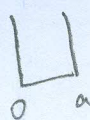
$$\frac{\ddot{x}}{2} = \frac{\omega^2}{a^2} \int x(x^2 - a^2) dx$$

$$\ddot{x} + \frac{k}{m} x - \frac{kx^3}{a^2 m} = 0$$

$$\ddot{x} = -\frac{\omega^2}{a^2} x(x^2 - a^2)$$

(7)

Q8.



$$\hat{p} = -i\hbar \frac{\partial}{\partial x}$$

$$-\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} - E \psi(x) = 0$$

$$a) \hat{H} \psi(x) = E \psi(x)$$

$$\frac{\hat{p}^2}{2m} \psi(x) = E \psi(x)$$

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{2mE}{\hbar^2} \psi(x) = 0 \quad k^2 = \frac{2mE}{\hbar^2}$$

$$A = -4k^2 \Rightarrow r = \pm k$$

$$\psi(x) = A e^{-kx} + B e^{kx} \Rightarrow \psi(x) = A \sin(kx)$$

$$x=0 \Rightarrow \psi=0 \quad x=a$$

$$\sin(ka) = 0 \Rightarrow k = \frac{n\pi}{a} \Rightarrow$$

$$\Rightarrow \psi(x) = \sqrt{\frac{2}{a}} \cdot \sin\left(\frac{n\pi}{a} x\right)$$

$$\int_0^a |\psi(x)|^2 dx = 1 \Rightarrow \frac{A^2}{2} a = 1 \Rightarrow A = \sqrt{\frac{2}{a}}$$

$$E = \frac{\hbar^2 k^2}{2m} = \frac{\hbar^2 n^2 \pi^2}{2a^2 m}$$

$$n=2 \Rightarrow E = \frac{2\hbar^2 \pi^2}{a^2 m}$$

$$b) \int_0^a A^2 \left[\sin^2\left(\frac{2\pi x}{a}\right) + 9 \sin^2\left(\frac{2\pi x}{a}\right) \right] dx = 1$$

$$\frac{A^2}{2} \int_0^a \left[10 + \cos\left(\frac{4\pi x}{a}\right) + 9 \cos\left(\frac{4\pi x}{a}\right) \right] dx = 1$$

$$\psi(x) = \sqrt{\frac{2}{a}} \sin\left(\frac{2\pi}{a} x\right)$$

$$P(\psi_2) = \frac{1}{5a} = \frac{9}{5a}$$

$$\frac{A^2}{2} \left[a + \left(-\sin\left(\frac{4\pi x}{a}\right) \cdot \frac{a}{4\pi} \right) + \left(-9 \sin\left(\frac{4\pi x}{a}\right) \cdot \frac{a}{4\pi} \right) \right]_0^a = 1$$

$$A = \sqrt{\frac{1}{5a}}$$

$$c) \psi_0 = \sqrt{\frac{1}{5a}} \sin\left(\frac{\pi x}{a}\right) \Rightarrow$$

$$\sin(x) = \frac{e^{+ix} - e^{-ix}}{2i}$$

$$\psi(p) = \frac{1}{\sqrt{2\pi\hbar}} \int dx e^{-\frac{i}{\hbar} p x} \psi(x)$$

$$\psi(p) = \frac{1}{\sqrt{2\pi\hbar}} \int_0^a \frac{1}{\sqrt{5a}} \left[e^{ix\left(-\frac{p}{\hbar} + \frac{\pi}{a}\right)} - e^{-ix\left(\frac{p}{\hbar} + \frac{\pi}{a}\right)} \right] dx$$

(8)

08.c)

EUF 2014-15m

10/03/2016

$$\psi(p) = \frac{-i}{2\sqrt{10\hbar a}} \left[\frac{-i e^{i\hbar(-\frac{p}{\hbar} + \frac{E}{\hbar})}}{(-\frac{p}{\hbar} + \frac{E}{\hbar})} - \frac{-i e^{i\hbar(\frac{p}{\hbar} + \frac{E}{\hbar})}}{(\frac{p}{\hbar} + \frac{E}{\hbar})} \right]_0^a$$

$$\psi(p) = \frac{-i}{2\sqrt{10\hbar a}} \left[\frac{e^{i\hbar(-\frac{p}{\hbar} + \frac{E}{\hbar})}}{(-\frac{p}{\hbar} + \frac{E}{\hbar})} - \frac{1}{(-\frac{p}{\hbar} + \frac{E}{\hbar})} + \frac{e^{i\hbar(\frac{p}{\hbar} + \frac{E}{\hbar})}}{(\frac{p}{\hbar} + \frac{E}{\hbar})} - 1 \right]$$

$$\psi(p) = \frac{-i e^{i\hbar \frac{p}{\hbar}}}{2\sqrt{10\hbar a}} \left[\frac{e^{i\hbar(-\frac{p}{\hbar} + \frac{E}{\hbar})} - 1}{(-\frac{p}{\hbar} + \frac{E}{\hbar})} + \frac{e^{i\hbar(\frac{p}{\hbar} + \frac{E}{\hbar})} - 1}{(\frac{p}{\hbar} + \frac{E}{\hbar})} \right]$$

d) $\psi(x) = e^{ikx}$

$$-\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial x^2} + 0 = E\psi$$

$$k^2 = \frac{2mE}{\hbar^2} \Rightarrow E = \frac{\hbar^2 k^2}{2m} = \hbar \omega \quad E = \frac{p^2}{2m} = \frac{\hbar^2 k^2}{2m}$$

09. $\vec{M} = \gamma \vec{S} : |+\rangle, |-\rangle, \hat{S}_z : \hat{S}_z |+\rangle = \frac{\hbar}{2} |+\rangle, \hat{S}_z |-\rangle = -\frac{\hbar}{2} |-\rangle$

$\vec{B} = B\hat{y}, \hat{H} = -\vec{M} \cdot \vec{B} = -\gamma B \hat{S}_y, |4(n)\rangle = |+\rangle$

a) $\hat{S}_y = \frac{\hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \Rightarrow \hat{S}_y |+\rangle = i\frac{\hbar}{2} |-\rangle, \hat{S}_y |-\rangle = -i\frac{\hbar}{2} |+\rangle$

$\hat{S}_z = \begin{pmatrix} \frac{\hbar}{2} & 0 \\ 0 & -\frac{\hbar}{2} \end{pmatrix} \Rightarrow \langle + | \hat{S}_z | + \rangle = \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \end{pmatrix} = \frac{\hbar}{2}$

b) $\begin{vmatrix} -\lambda & -i\hbar/2 \\ i\hbar/2 & -\lambda \end{vmatrix} = 0 \Rightarrow \lambda^2 - 1 = 0 \Rightarrow \lambda = \pm \frac{\hbar}{2}$

$\Rightarrow \frac{\hbar}{2} \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} = \frac{\hbar}{2} \begin{bmatrix} a \\ b \end{bmatrix} \Rightarrow \begin{bmatrix} 1 \\ i \end{bmatrix} \Rightarrow |+\rangle = A[|+\rangle + i|-\rangle]$

$-ib = \frac{\hbar}{2}a \quad ia = \frac{\hbar}{2}b \quad 2A^2 = 1 \quad A = \frac{1}{\sqrt{2}}$

9) $b = \frac{\hbar}{2}a$

$$c) |\psi(0)\rangle = |+\rangle$$

$$\hat{H} = -\gamma B \hat{S}_y = -\gamma B \cdot \frac{\hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} = -\gamma B \left(\frac{i\hbar}{2} |-\rangle - \frac{i\hbar}{2} |+\rangle \right)$$

$$\omega = \gamma B \Rightarrow \hat{H} = -\frac{\omega \hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$$

$$|\psi(t)\rangle = a(t)|+\rangle + b(t)|-\rangle = \begin{pmatrix} a(t) \\ b(t) \end{pmatrix}$$

$$i\hbar \frac{\partial \psi(t)}{\partial t} = \hat{H} \psi(t)$$

$$i\hbar \frac{d}{dt} \begin{pmatrix} a(t) \\ b(t) \end{pmatrix} = -\frac{\omega \hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \begin{pmatrix} a(t) \\ b(t) \end{pmatrix}$$

$$i\hbar \dot{a}(t) = +i\frac{\omega \hbar}{2} = +\frac{\omega}{2} a(t) ; \quad \dot{b}(t) = -\frac{\omega}{2} b(t)$$

$$\ln(a(t)) = \frac{\omega t}{2} \Rightarrow a(t) = e^{\frac{\omega t}{2}} \cdot a(0) ; \quad b(t) = b(0) \cdot e^{-\frac{\omega t}{2}}$$

$$|\psi(t)\rangle = a(0) \cdot e^{\frac{\omega t}{2}} |+\rangle + b(0) e^{-\frac{\omega t}{2}} |-\rangle$$

$$|\psi(0)\rangle = a(0)|+\rangle + b(0)|-\rangle \Rightarrow b(0) = 0, \quad a(0) = 1$$

$$|\psi(t)\rangle = e^{\frac{\omega t}{2}} |+\rangle$$

$$d) \langle S_x \rangle = \langle \psi(t) | S_x | \psi(t) \rangle$$

$$S_x = \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \Rightarrow \left(e^{\frac{\omega t}{2}} 0 \right) \cdot \frac{\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \cdot \begin{pmatrix} e^{\frac{\omega t}{2}} \\ 0 \end{pmatrix} = \frac{\hbar}{2} \begin{pmatrix} e^{\frac{\omega t}{2}} & 0 \end{pmatrix} \begin{pmatrix} 0 \\ e^{\frac{\omega t}{2}} \end{pmatrix} = 0$$

h)

EVF 2014 - 15m.

11/03

d)

$$\langle s_y \rangle = \langle \psi(t) | s_y | \psi(t) \rangle = \begin{pmatrix} e^{-\frac{it}{2}} & 0 \end{pmatrix} \left(-\frac{i\hbar}{2} \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \right) \begin{pmatrix} e^{\frac{it}{2}} \\ 0 \end{pmatrix}$$

$$\hat{s}_y = \frac{\hbar}{2} \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$$

$$= -\frac{i\hbar}{2} \cdot \begin{pmatrix} e^{-\frac{it}{2}} & 0 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \end{pmatrix} = 0$$

$$\langle \hat{s}_x \rangle = \begin{pmatrix} e^{-\frac{it}{2}} & 0 \end{pmatrix} \frac{\hbar}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} e^{\frac{it}{2}} \\ 0 \end{pmatrix} = \begin{pmatrix} e^{-\frac{it}{2}} & 0 \end{pmatrix} \frac{\hbar}{2} \begin{pmatrix} e^{\frac{it}{2}} \\ 0 \end{pmatrix}$$

$$\hat{s}_x = \frac{\hbar}{2} \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

?

$$= \frac{\hbar}{2} \cdot e^{-\frac{it}{2}} \cdot e^{\frac{it}{2}} = \frac{\hbar}{2}$$

Q12 a) $z = \sum_n e^{-\beta \epsilon_n} = e^{-\beta \mu_H} + 2 \Rightarrow \ln(e^{-\beta \mu_H} + 2)$

$$Z = z^N = (e^{-\beta \mu_H} + 2)^N$$

$$F = -k_B T \ln Z = -\frac{N}{\beta} \ln(e^{-\beta \mu_H} + 2) = -\frac{N}{\beta} \left[\ln \left[e^{-\beta \mu_H} (1 + 2e^{\beta \mu_H}) \right] \right]$$

$$= -\frac{N}{\beta} \cdot [\beta \mu_H + \ln(1 + 2e^{\beta \mu_H})] \quad \text{2. Schritt}$$

b) $U = -\frac{\partial \ln Z}{\partial \beta} = \frac{1}{(e^{-\beta \mu_H} + 2)} \cdot (\mu_H) e^{-\beta \mu_H}$

$$I = -k_B T \ln Z = -\frac{1}{\beta} \ln(e^{-\beta \mu_H} + 2)$$

$$\lambda = \frac{I - U}{T}$$

11

$$c) \langle \mu_n \rangle = m = \mu \sum_{i=1}^N \bar{a}_i \Rightarrow M = -\frac{\partial \Phi}{\partial H} = -\frac{1}{\beta} \cdot \frac{1}{(e^{\beta H} + 1)} \cdot \beta N = \boxed{\frac{N}{e^{\beta H} + 1}} \quad \times$$

$$2) \chi_T = \left(\frac{\partial m}{\partial A} \right)_T$$

$$\langle \mu_n \rangle = m_x \hat{x} + m_y \hat{y} = \mu \hat{g}$$

$$m_x = \mu \hat{x} + (-\mu \hat{y}) = 0 \quad ?$$

$$m_y = \mu \cdot P(\mu_y) \hat{y} =$$